

IPNS Accelerator Diagnostics

Jeff Dooling, Walter Czyz, Marvin Lien
Argonne National Laboratory

presented to the
11th ICFA International Mini-Workshop on
Diagnostics for High-Intensity Hadron Machines

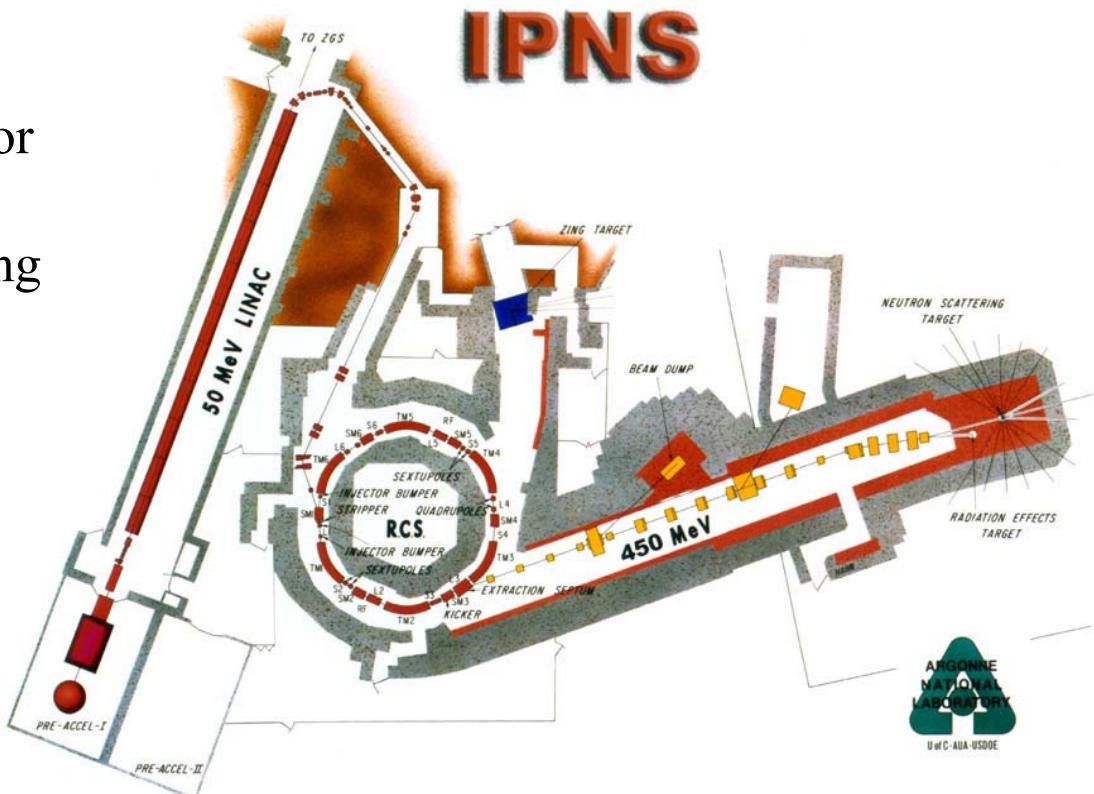
Spallation Neutron Source
Oak Ridge, Tennessee

October 21-23, 2002



IPNS ACCELERATOR FACILITY

- **Source and three accelerators**
 - 750 keV Pre-accelerator
 - 50 MeV Linac
 - 450 MeV Rapid Cycling Synchrotron (RCS)
 - **Transport lines**
 - Column to Linac
 - 50 MeV
 - PTS (450 MeV)

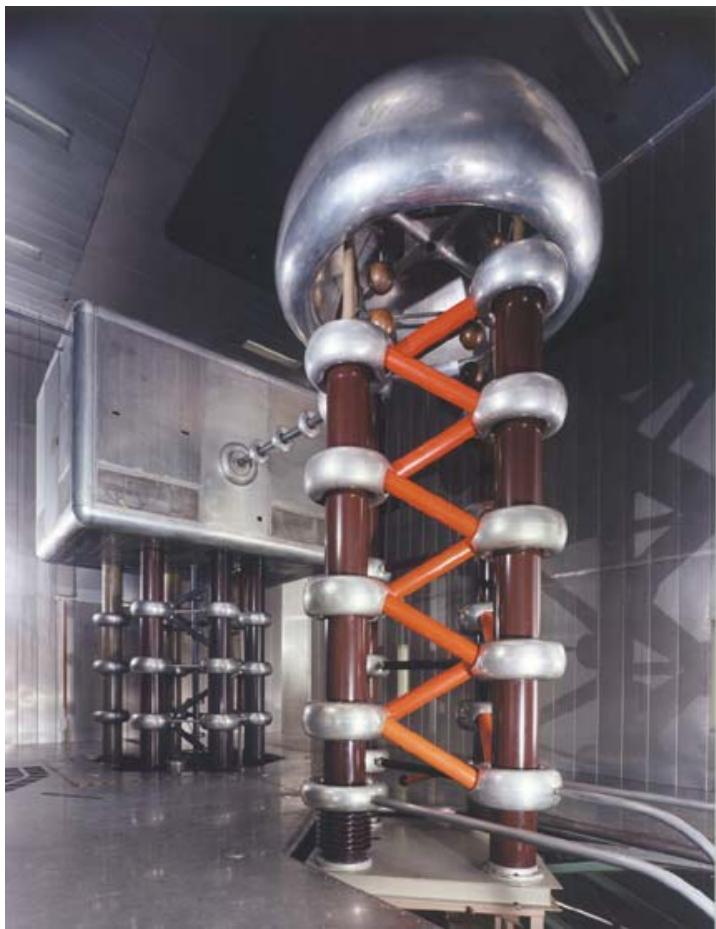


Diagnostics

- Source/Pre-accelerator
 - CTs (Home-built (HB))
- Column to Linac
 - CTs (Pearson and HB)
 - RF p.u.
- Linac
 - CTs (Pearson and HB)
 - ESEM (strip-lines, output)
 - Scintillator (output)
 - RF p.u.
- 50 MeV Transport Line
 - CT (Pearson)
 - Liquid Scintillator LM
 - Wire Scanners
- 50 MeV Transport Line, con't
 - Strip-line BPMs
 - Segmented Faraday Cup
 - Scintillator
- RCS
 - CTs (Pearson)
 - Segmented Faraday Cup
 - Pie-electrodes (split can)
 - PAPS
 - RF Gap p.u. (cap. divider)
 - RWM
 - RFA (new)
- PTS (450 MeV Line)
 - CTs (Pearson and Bergoz)
 - SWICs
 - SSEMs

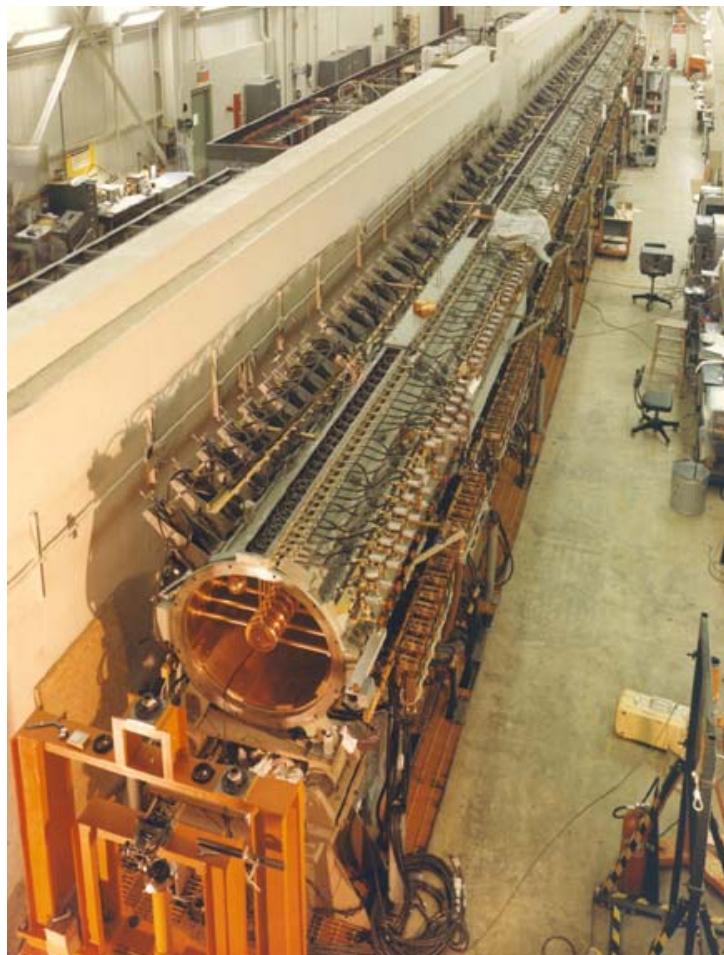


ION SOURCE AND PREACCELERATOR



- Magnetron-type H⁻ ion source, cesium getter
- Extraction at 20 keV, magnet to separate electrons
- Cockcroft-Walton generator, 750 kV
- Output H⁻ beam, 30 mA peak, 70 µs pulses, 30 Hz

LINAC



- Alvarez-type “drift-tube linac”
- Copper-clad steel tank, 33.5-m long, 0.93-m diameter
- 124 drift tubes, each with a dc quadrupole magnet
- 200-MHz rf transmitter, triode amplifier tube, 3 MW
- Output H⁻ beam 50 MeV, 10-mA peak, 70 µs pulses, 30 Hz

50 MEV TRANSPORT LINE

- 8 Horizontal 30° sector magnets
- 6 Vertical steering dipole magnets
- 16 Quadrupole focusing magnets
- 12 wire scanners, 7 strip-line BPMs, 2 Faraday cups,
2 scintillators
- Transports H⁻ beam \approx 40 m from linac to RCS; significant dispersion near WS7 (D=6 m)

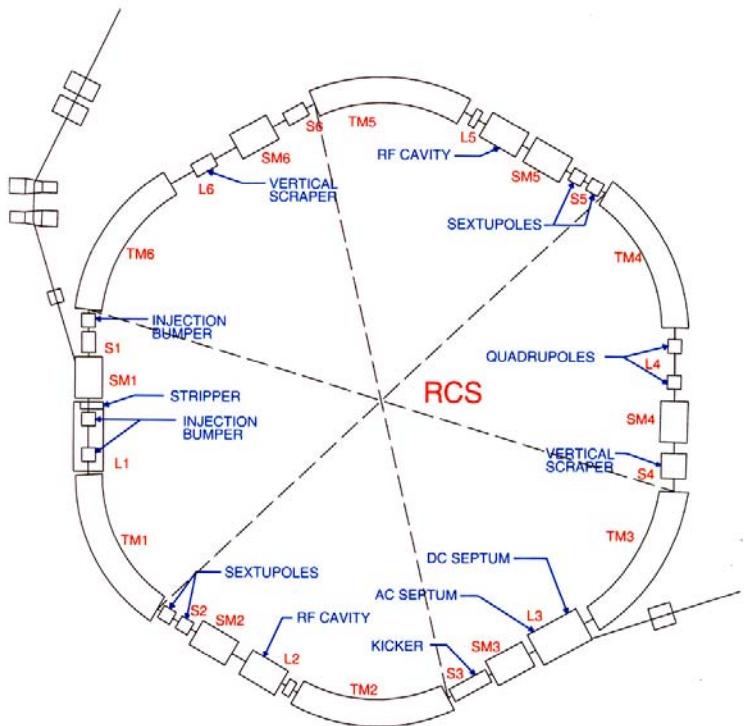


RAPID CYCLING SYNCHROTRON “RCS”



- 43-m circumference strong-focusing, combined-function synchrotron.
- 6-sector machine, magnet structure D00FDF0.
- Betatron tune correction provided by single pair of pulsed quads; chromaticity control by two pairs of pulsed sextupole magnets.
- Two rf cavities, presently working on third.
- Single-turn extraction by two ferrite-loaded kicker magnets and two septum magnets.

RAPID CYCLING SYNCHROTRON “RCS”



- Ring magnets part of a 30 Hz resonant circuit. Central bending field varies from 0.28 to 0.94 Tesla during the accelerating cycle.
- Multi-turn, coasting beam injection (≈ 150 turns)
- Carbon foil, $55 \mu\text{g}/\text{cm}^2$
- Output proton beam 450 MeV, 40-50 ns pulse FWHM, 30 Hz, 3×10^{12} protons/pulse.

PTS TRANSPORT LINE



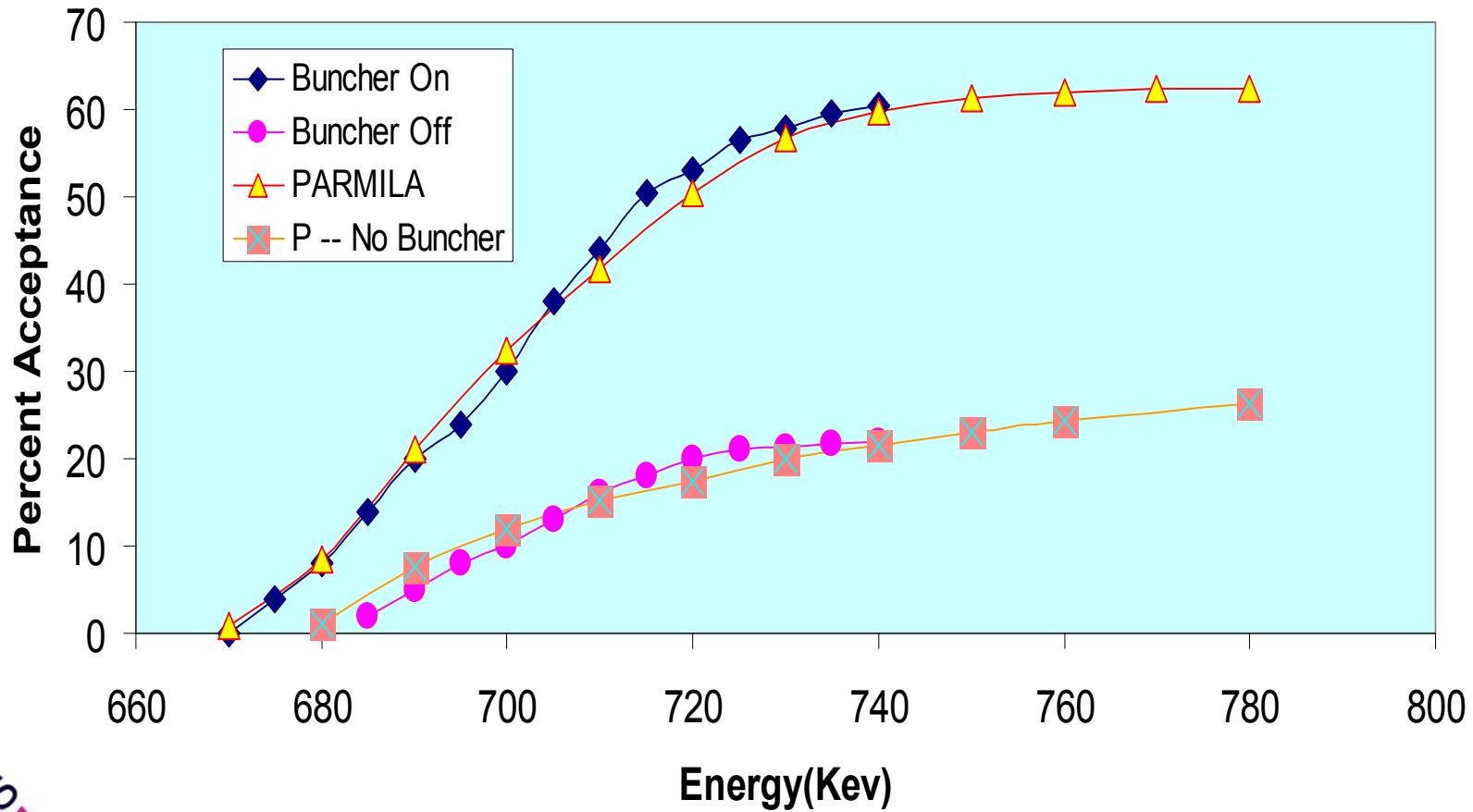
- 4 Horizontal bending magnets
- 2 Vertical steering magnets
- 15 Quadrupole focusing magnets
- 6 Segmented secondary emission monitors
2 Segmented wire ion chamber
- Transports H⁺ beam ≈ 45 m from RCS to neutron-generating target

Diagnostics

**COLUMN to LINAC,
LINAC,
and
50 MEV TRANSPORT LINE**



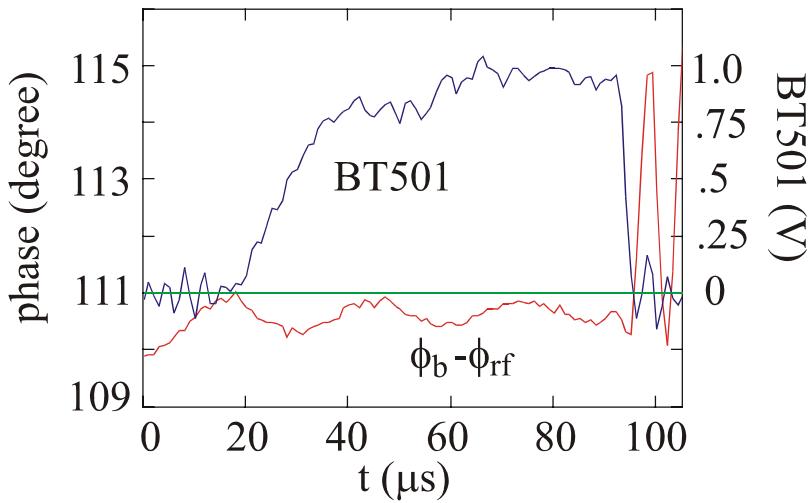
CTs yielding Transmission Efficiency Modeling—PARMILA



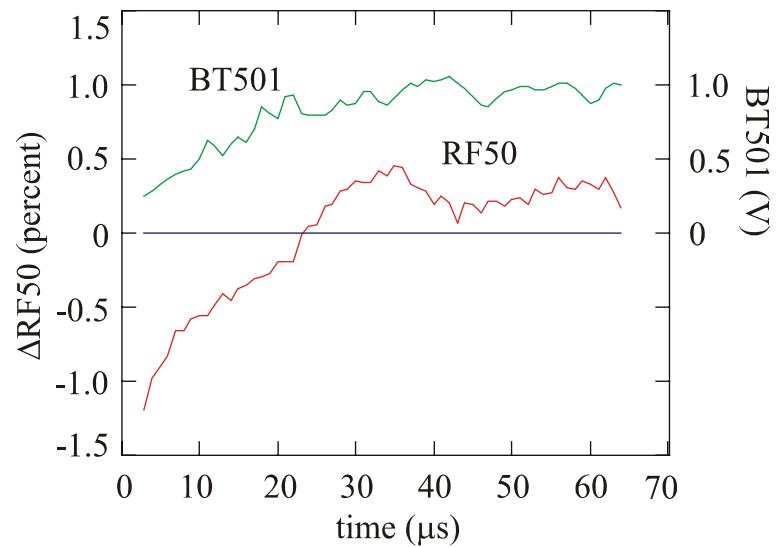
Diagnostics—RF pick-ups

Buncher-LINAC phase and LINAC gradient

- Cavity driven phase



- Gradient

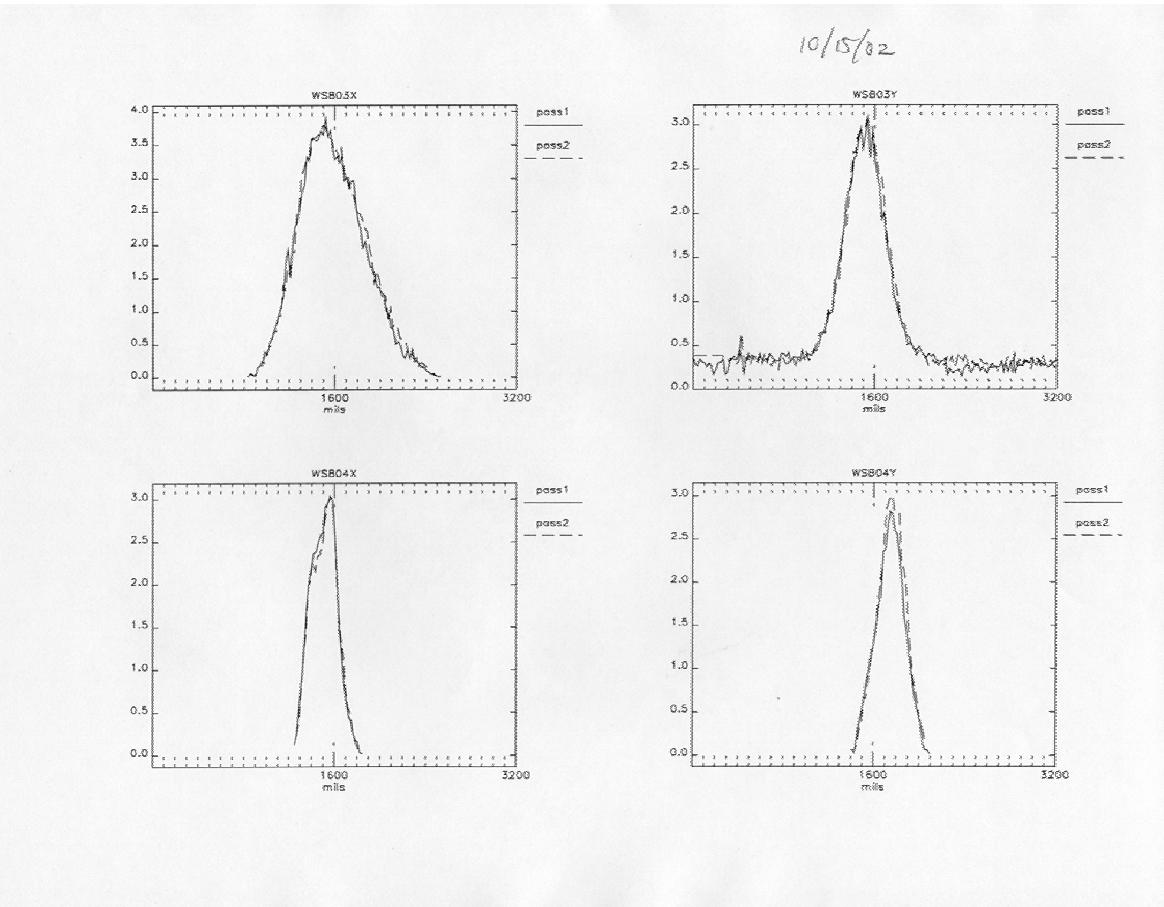


Wire Scanners

Transverse profiles (H and V)

WS3

H



WS4

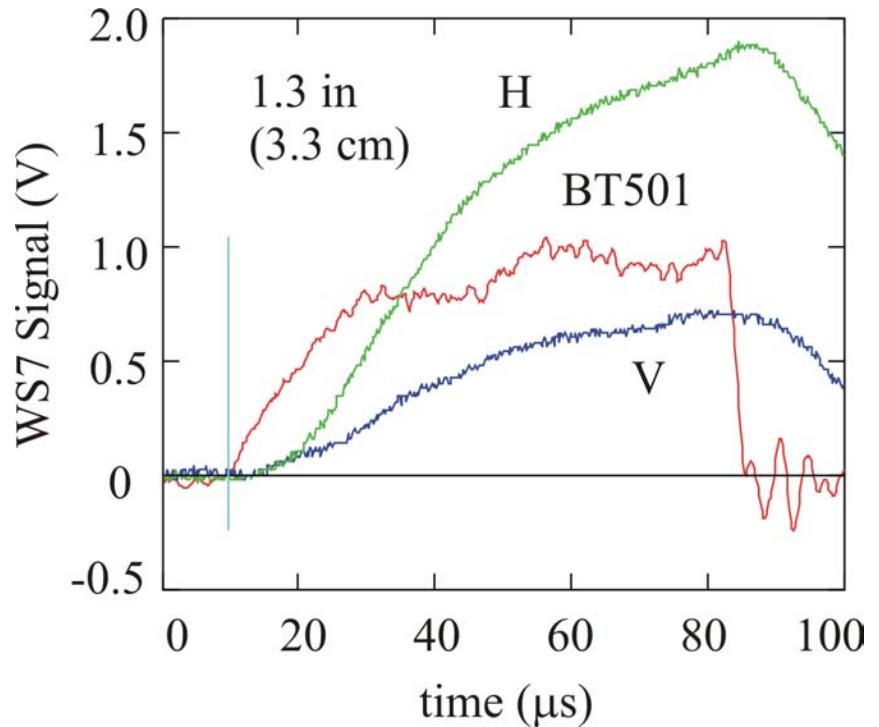


Stationary Wire

Transverse and temporal profiles

- Temporal signals, position slice
- Repeat slice every 2.5 mm (0.1 in)
- Generate (I, ζ, t) surface where $\zeta: x, y$

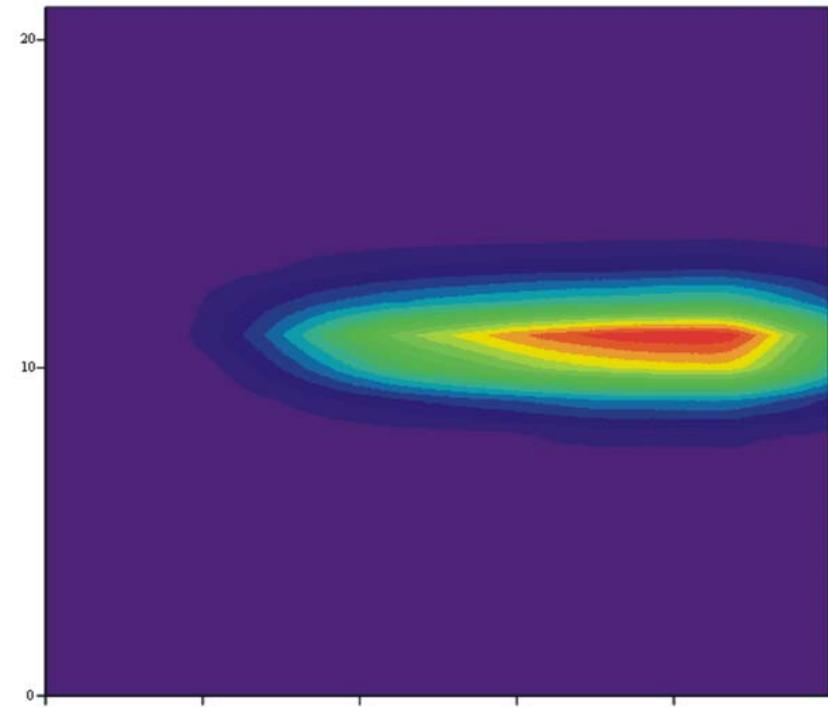
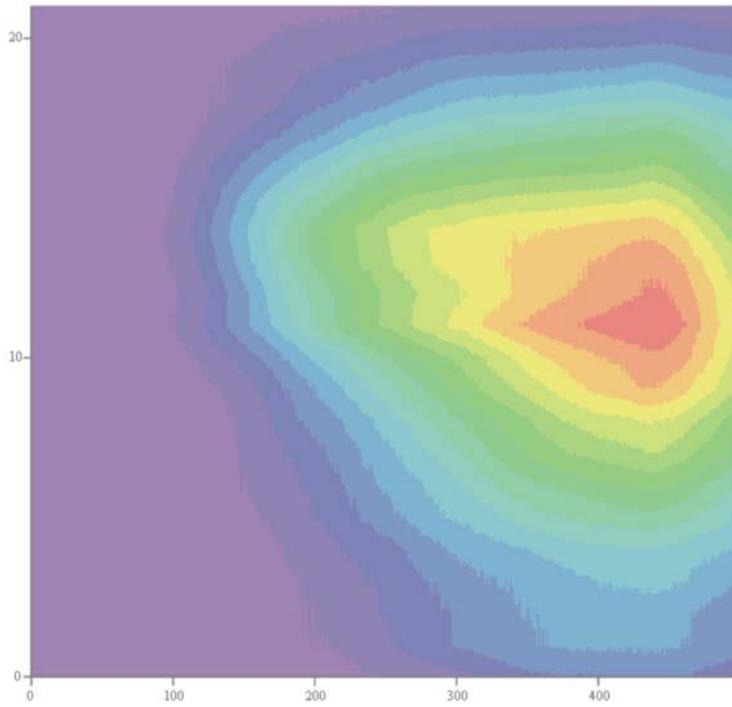
- Temporal profiles



Stationary Wire

Transverse-temporal intensity contours

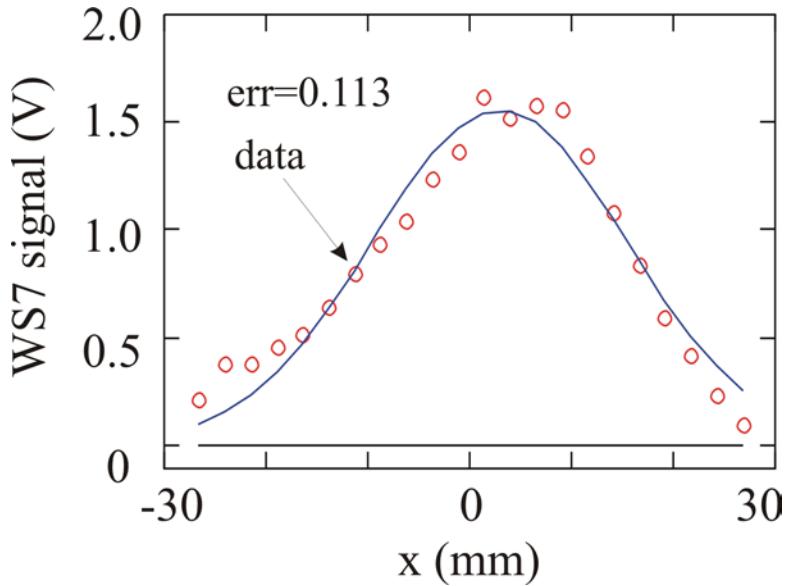
- Horizontal (20020430)
- Vertical (20020430)



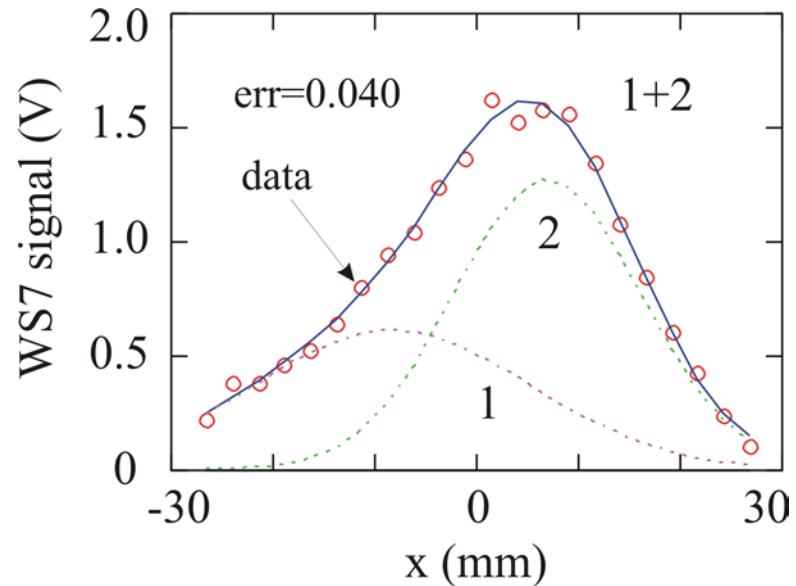
Stationary Wire

Reconstruct spatial profiles and fit

- Single Gaussian



- Double Gaussian



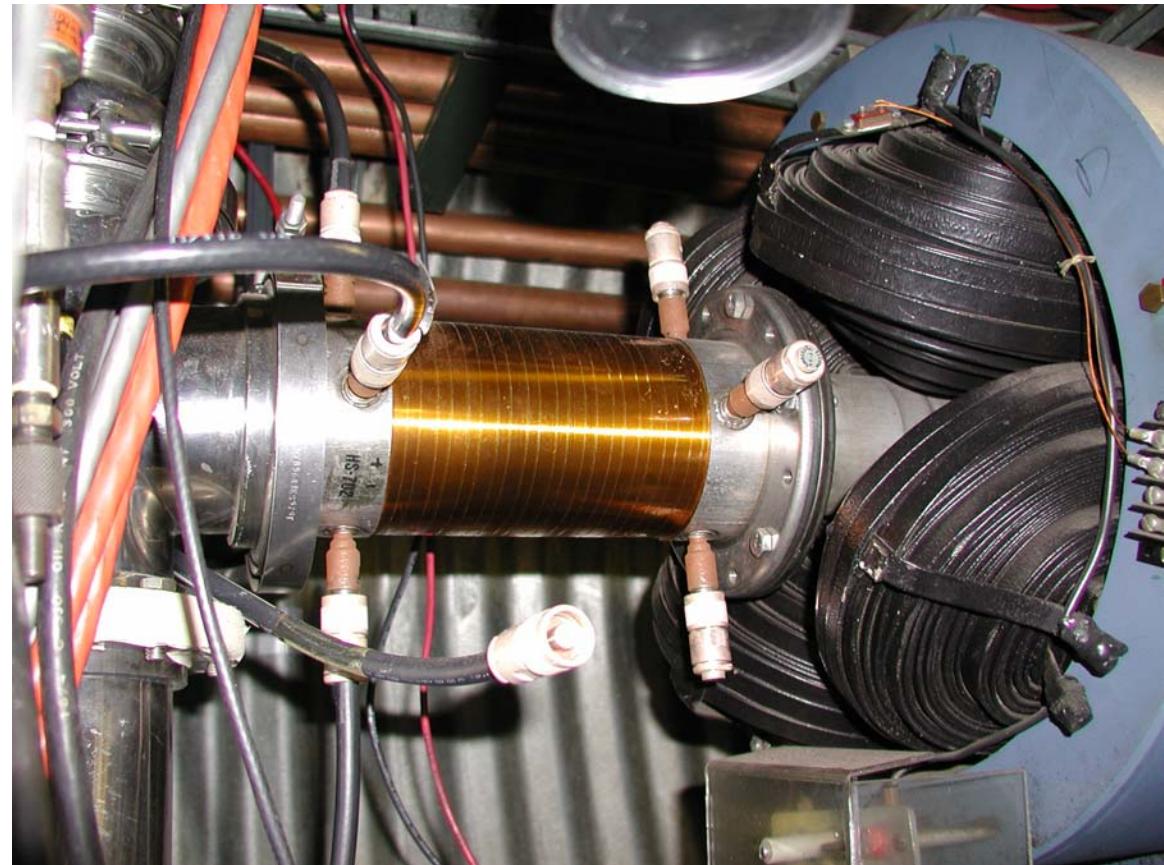
Terminated strip-line BPMs Beam Centroid in the 50 MeV Line

- R. Shafer design



Terminated strip-line BPMs Beam Centroid in the 50 MeV Line

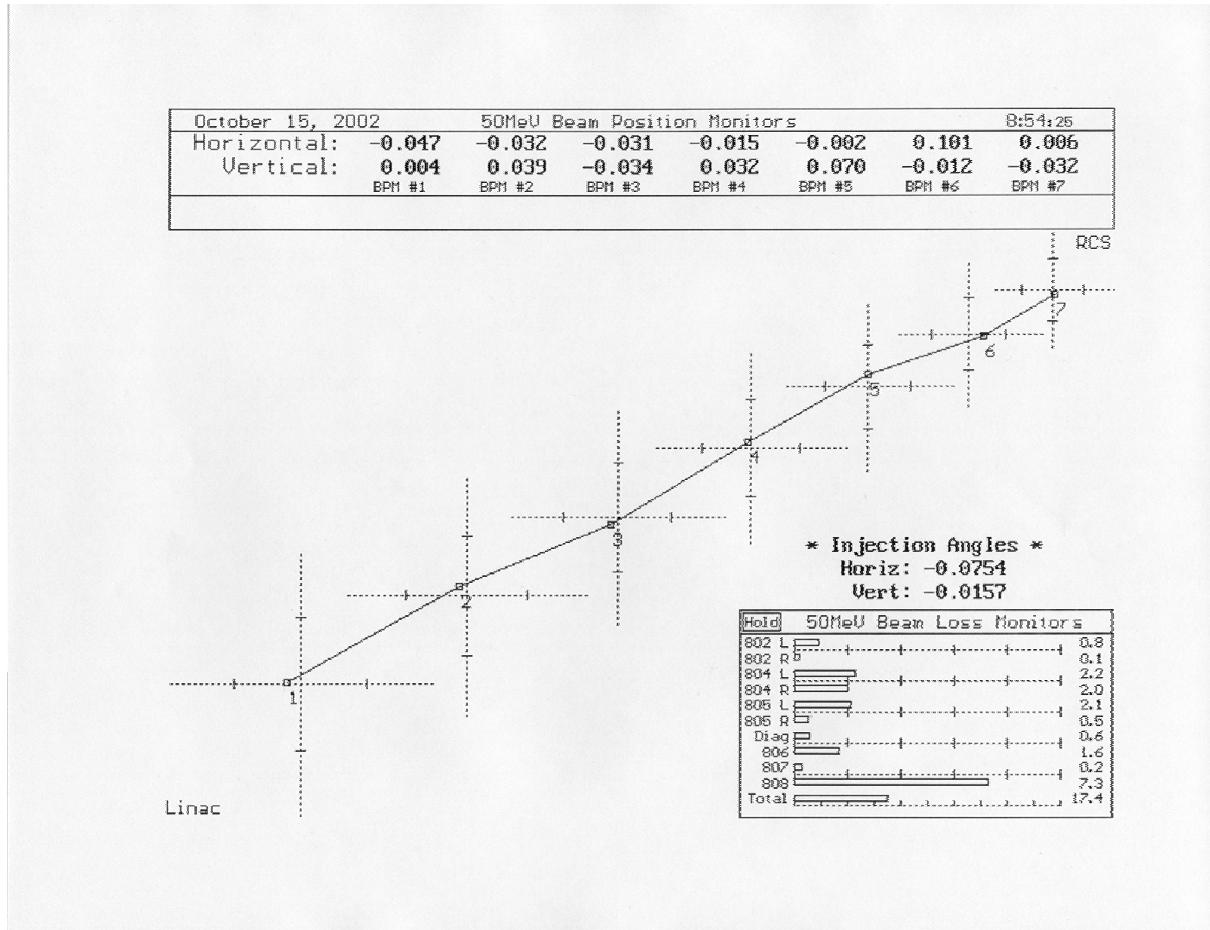
- BPM1
- Beam moves from left to right



Terminated strip-line BPMs

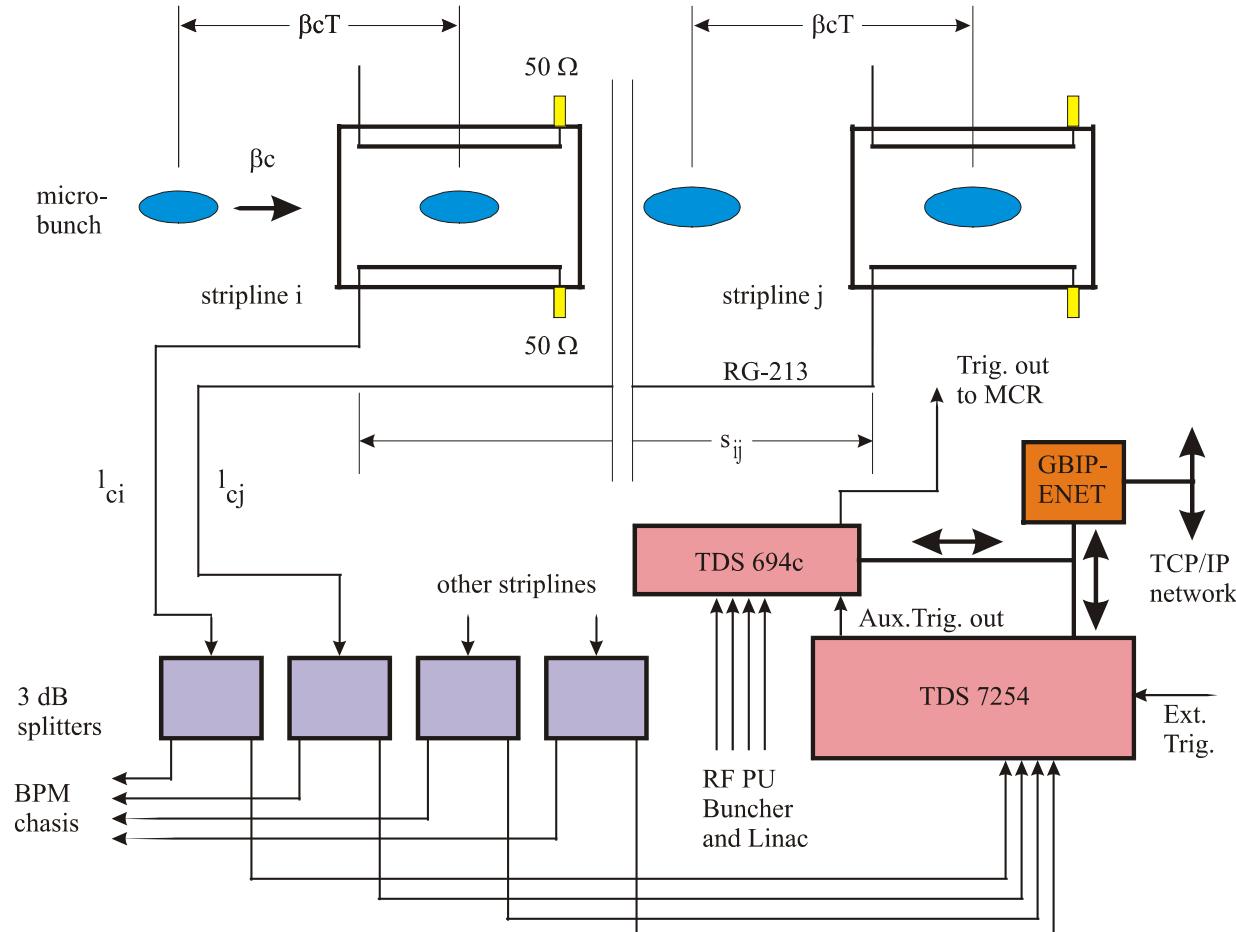
Beam Centroid in the 50 MeV Line

- MCR display



ESEM, strip-line BPMs

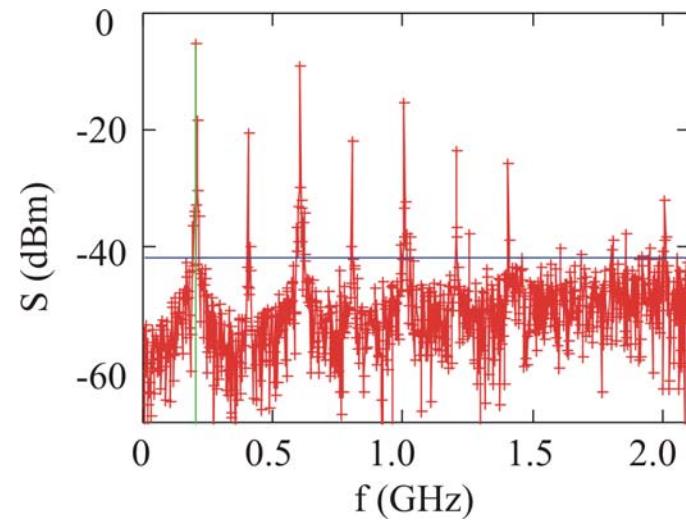
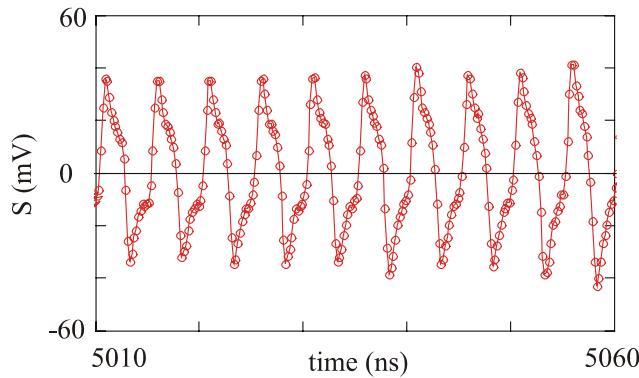
Energy and Energy Spread out of Linac



ESEM, strip-line BPMs

Energy and Energy Spread out of Linac

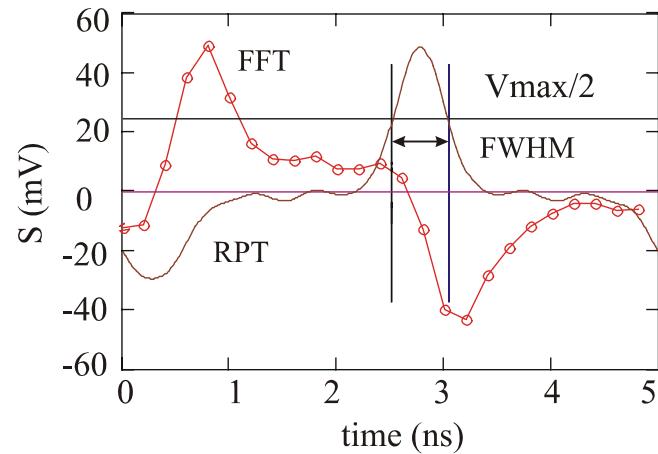
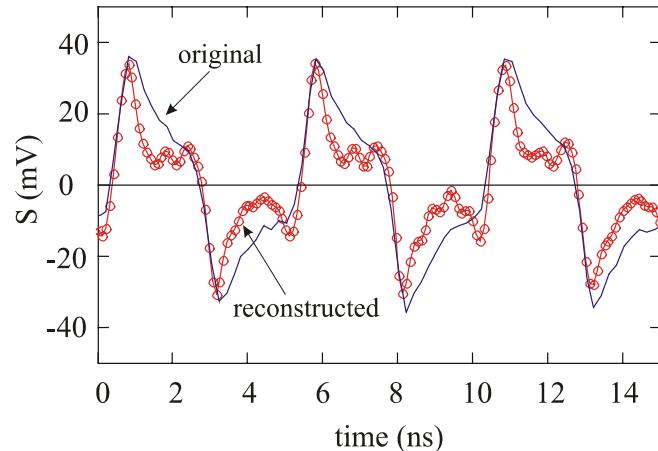
- BPM 1 signal, 50 μ s into linac macro-pulse. Sampling at 5GS/s from the bottom strip
- Convert to frequency domain to filter noise and correct for cable attenuation



ESEM, strip-line BPMs

Energy and Energy Spread out of Linac

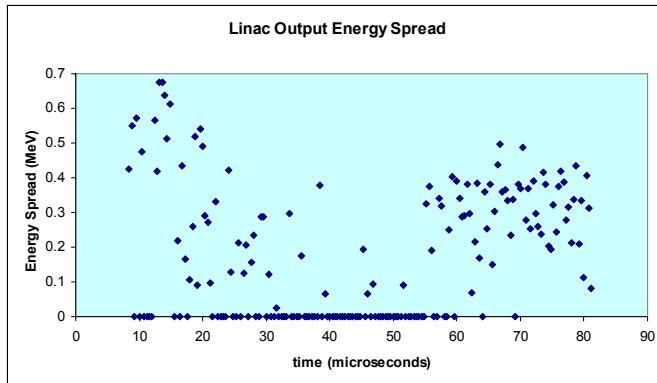
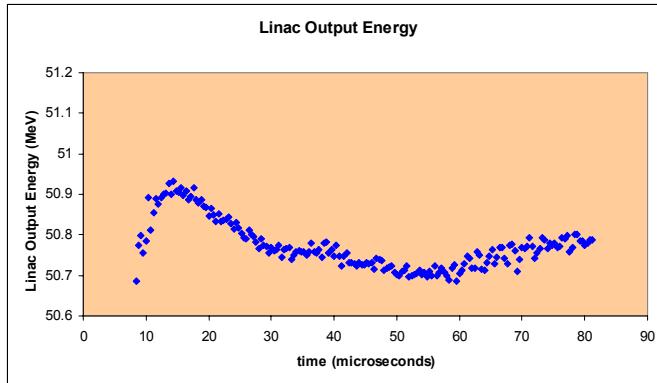
- Reconstruct waveform in the time domain from the primary harmonics
- Energy from TOF, FFT phasing
- Energy Spread from 3-size measurements, RPT phasing (4 permutations of 3)



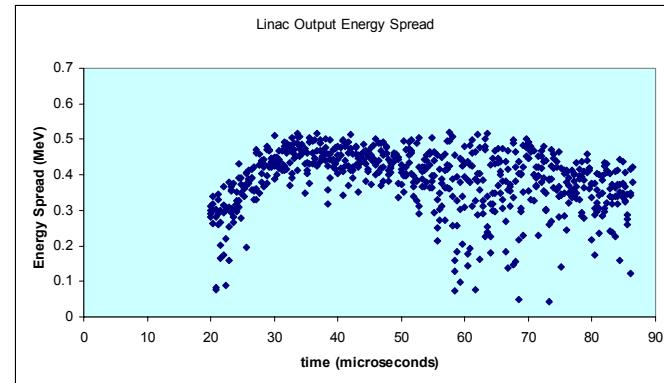
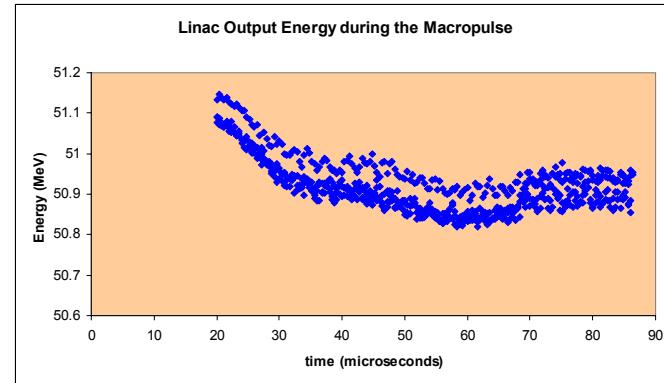
ESEM, strip-line BPMs

Energy and Energy Spread out of Linac

- October 2002, 15 μA

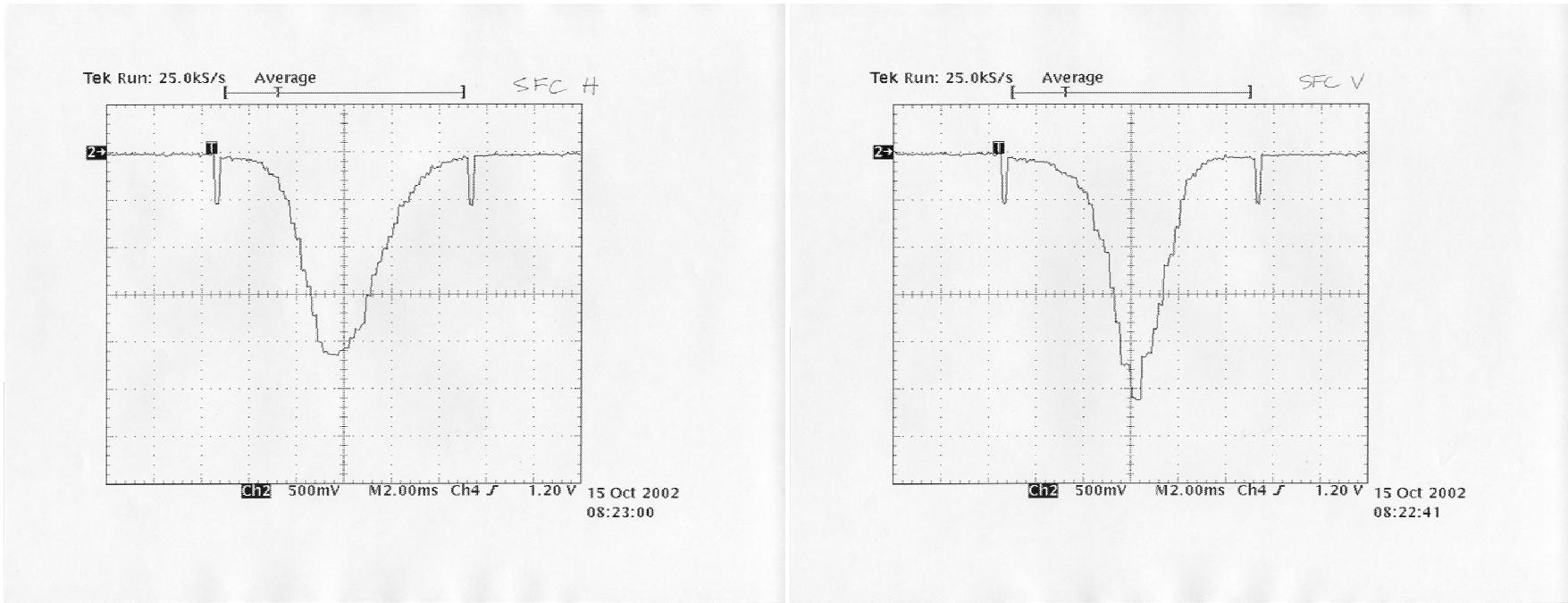


- December 2001, 16.2 μA



Segmented Faraday Cup

- Linac exit and ATLAS target location (H and V):



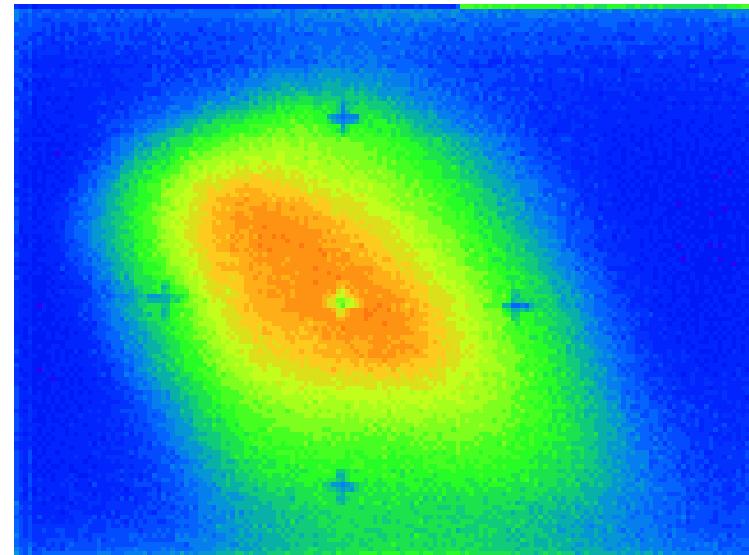
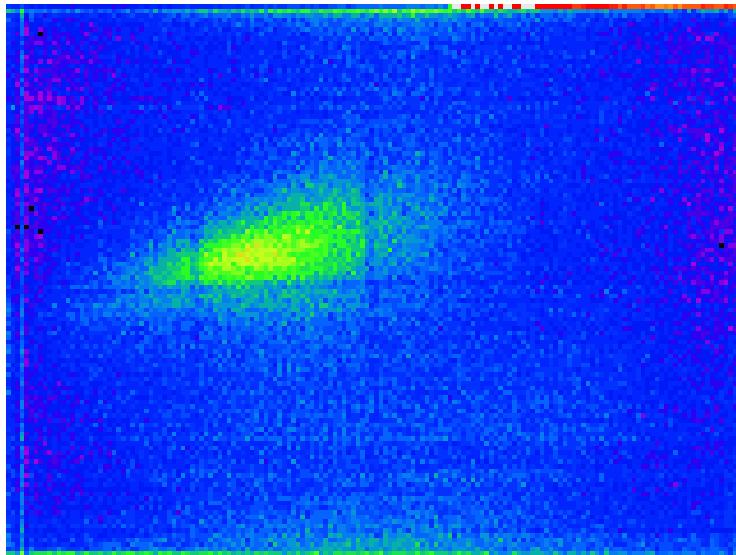
Scintillators

50 MeV line “D0” and “ATLAS”

D0 (linac output)

H^0 from gas stripping

ATLAS target (H^-)

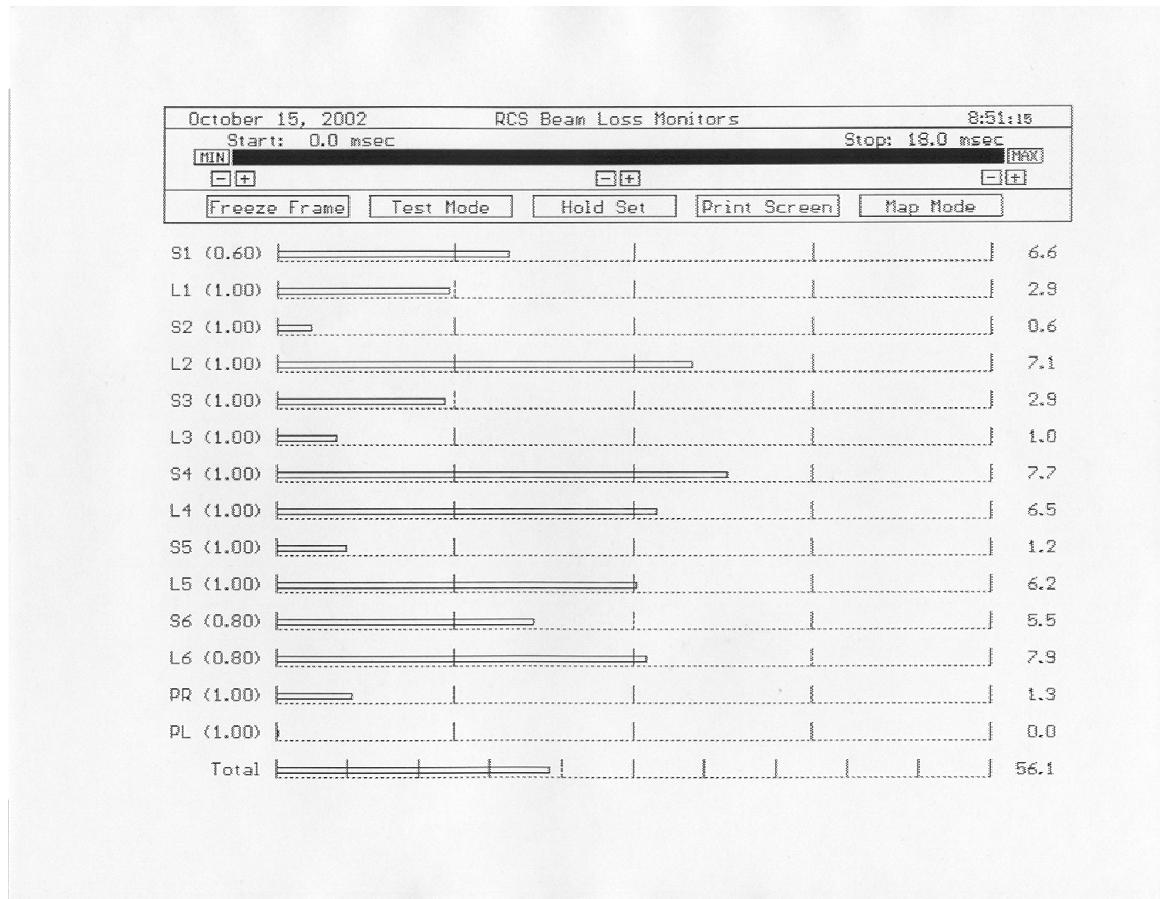


Diagnostics—30 Hz, Rapid Cycling Synchrotron (RCS)



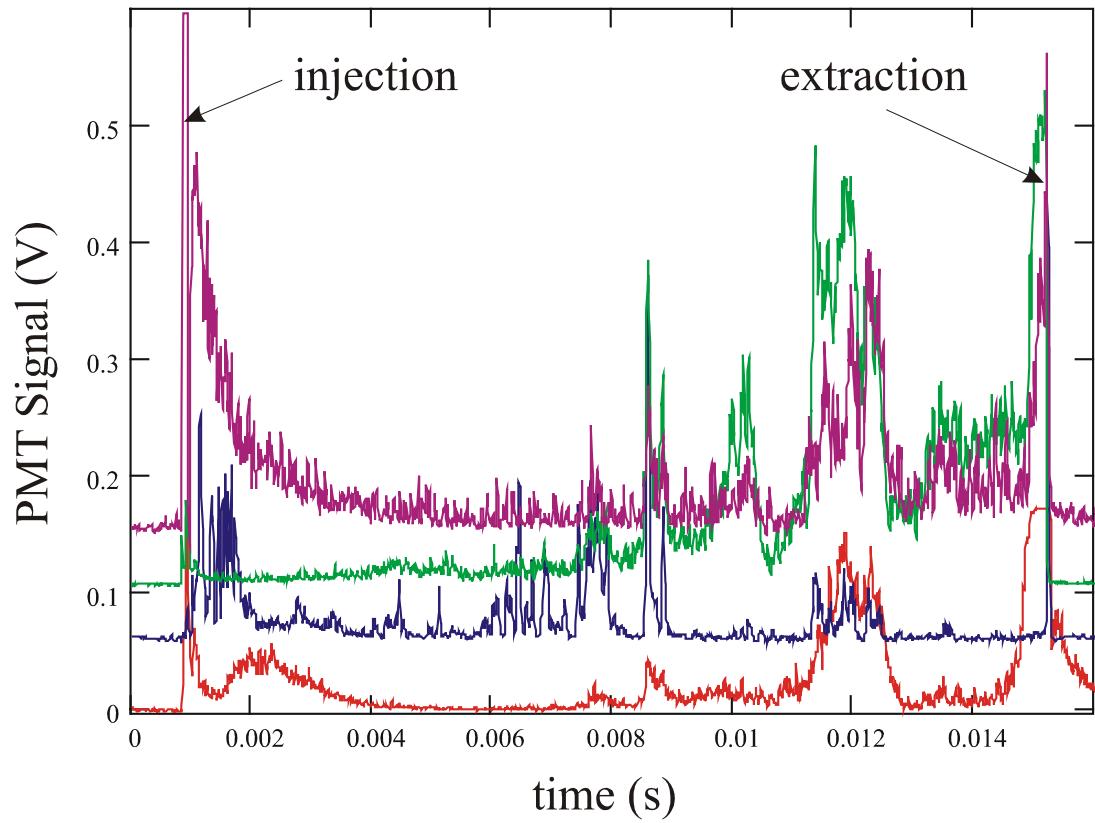
RCS Loss Monitors

- IPNS Runs Loss Limited—total losses < 0.6E12 protons



RCS Loss Monitors

- Provides information on when and where losses are occurring



Split Can “Pie” electrodes

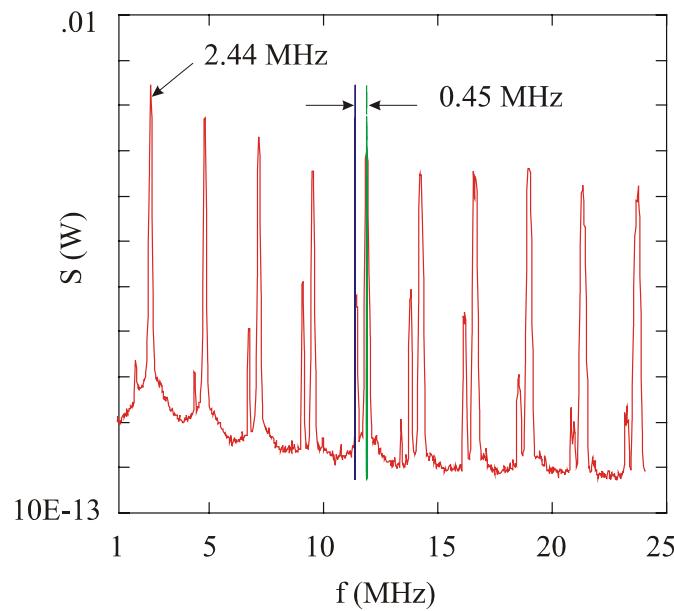
- Provides fast phase signals for the rf
- Radial position
- Recently used to examine transverse beam motion
- Output di/dt inside, outside, top, and bottom



Split Can “Pie” electrodes coherent dipole oscillation 2 ms after injection

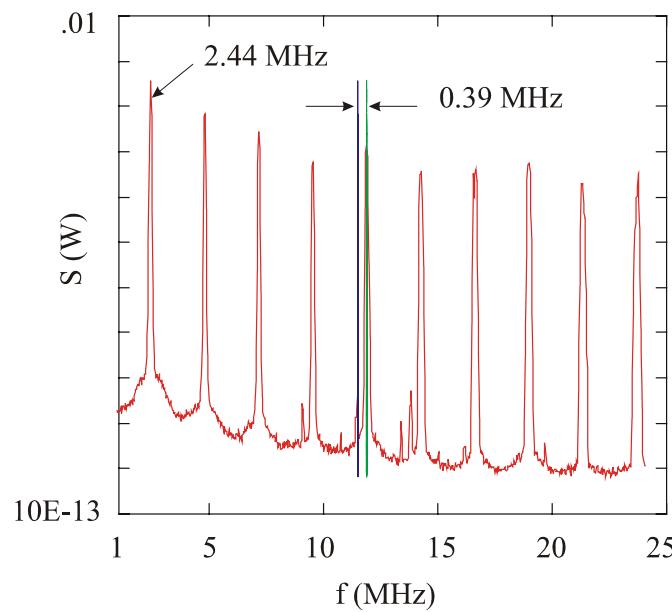
- Horizontal

$S=6.1\text{E-}9 \text{ W}$



- Vertical

$S=4.1\text{E-}11 \text{ W}$



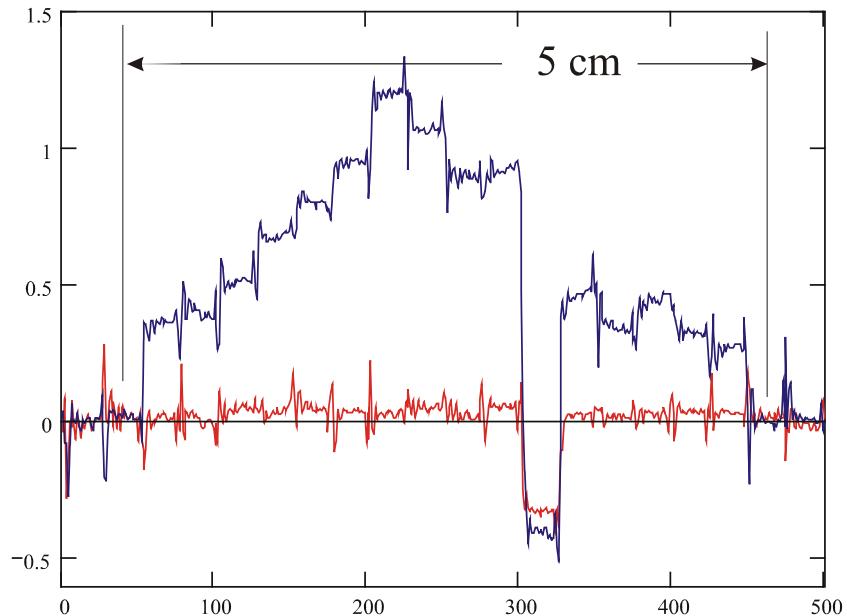
Resistive Wall Monitor

- Purely longitudinal (similar to CT but with higher BW)
- May lose with third cavity



Profile and Position System (PAPS)

- BW ~ 5 kHz
- Detects ionization electrons
- Horizontal profile has best aspect ratio (16 channels)



Proton Transport System (PTS) 450 MeV transport line diagnostics

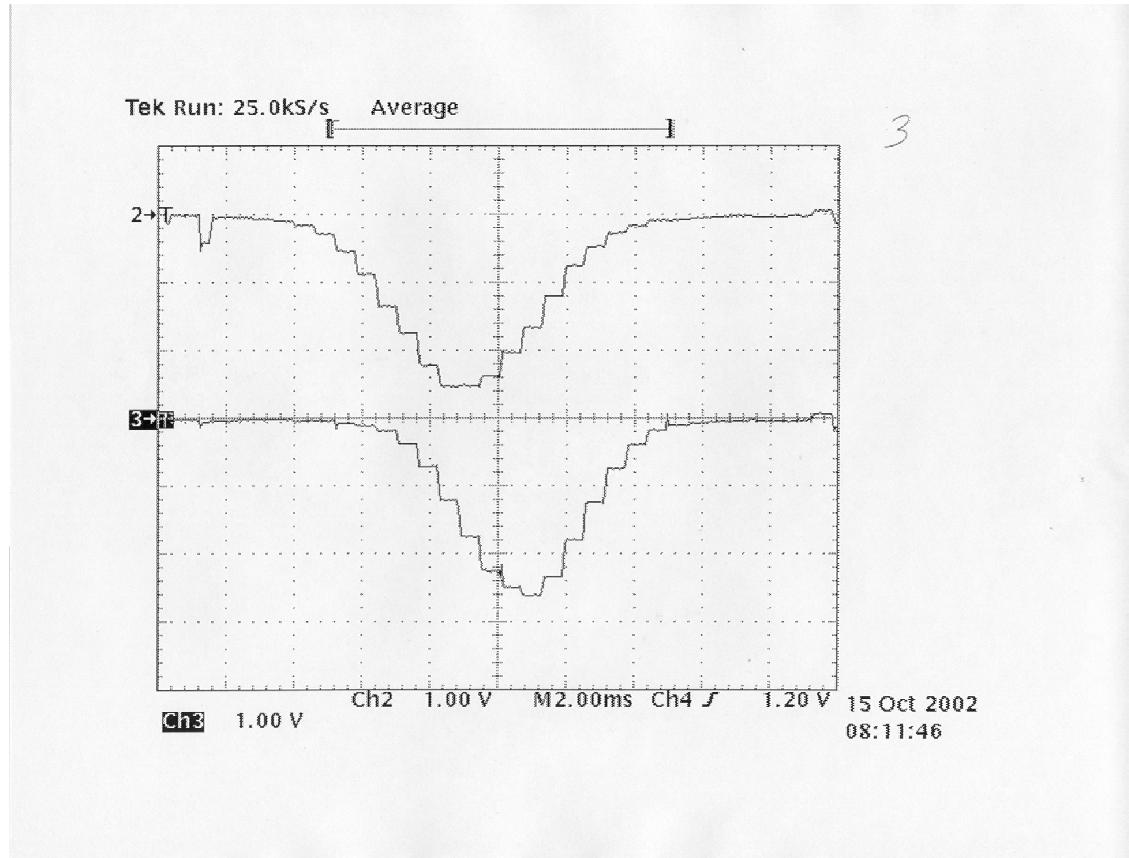


Toroids

- Pearson, Model 1010, 75 cm ID (10-3/4 in.)
20-MHz BW, 0.5 V/A; into $50\text{-}\Omega$, 0.25 V/A
- Bergoz (new), ICT 238-070-50:1 H (rad hardened), 238 mm ID, 288 mm OD, 0.5 V/A;
into $50\text{-}\Omega$, 0.25 V/A

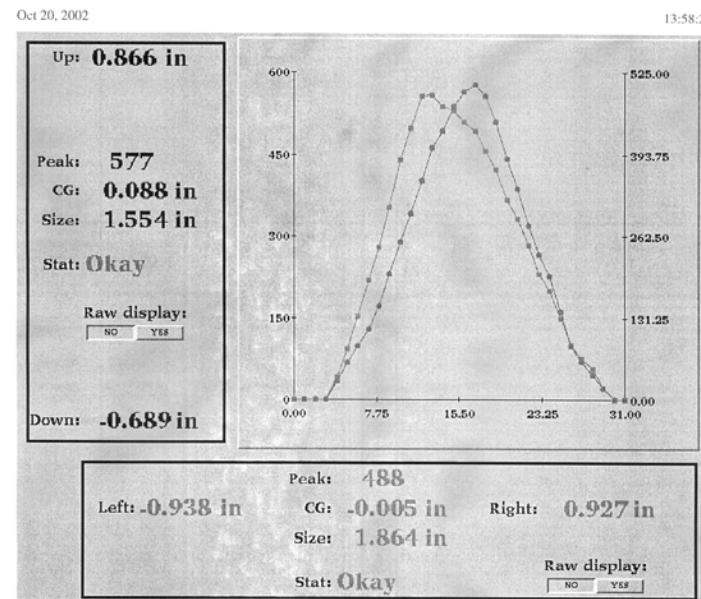
Segmented Secondary Emission Monitors (SSEM)

- Provide profile and centroid information
- Low energy (≤ 5 Hz)



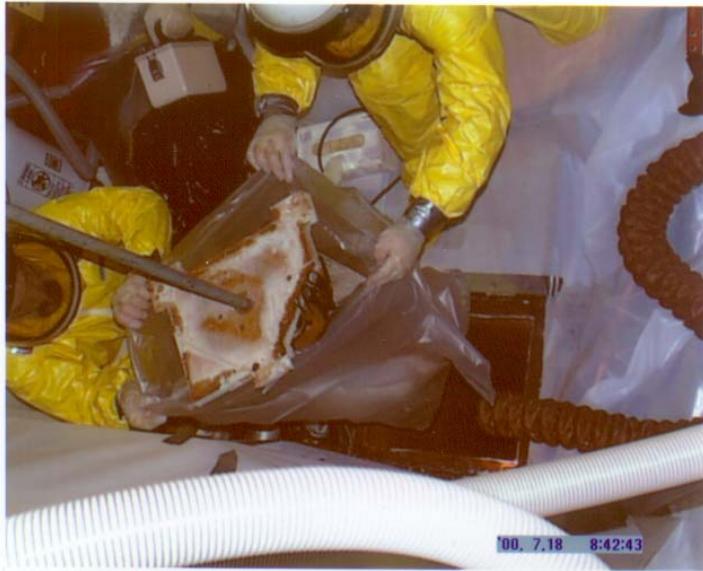
Segmented Wire Ionization Chambers (SWIC) and Position and Size (PAS) detector

- On-line position and size monitors
- Downstream SWIC/PAS—receives full beam all the time
- Must be periodically replaced



Segmented Wire Ionization Chambers (SWIC) and Position and Size (PAS) detector

- Replacing the SWIC/PAS package (out with the old and in with the new):



References

- R. Schafer, IEEE Trans. Nuc. Sci., **32**(5), 1933 (1985).
- S. L. Kramer, Third European Particle Accelerator Conf. (EPAC), Berlin, p. 1064(1992)
- J.C. Dooling, et al., 20th LINAC Conf., SLAC-R-561, Monterey, CA, Aug. 2000, p 193.
- A. V. Rauchas, et al., IEEE Trans. Nuc. Sci., **28**(3), 2338 (1981).
- R. A. Rosenberg, K. C. Harkay, NIM A, **453**, 507(2000).



SUMMARY

- Presently—
 - Good set of existing front end diagnostic devices
 - Looking at some of their information in new ways
- Into the Future—
 - To examine electrons and possible plasma, may want to look at microwave or far-ir interferometry
 - RGA might be useful to see if high charge state wall ions enter the beam (may lead to enhanced scattering)

